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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

The evaluation and quality control of seasonal climate forecasts in the C3S

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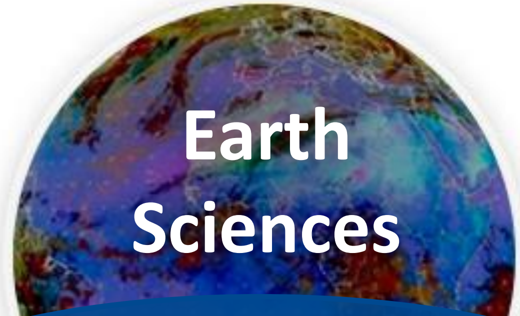
BSC scientific departments

To influence the way machines are built, programmed and used: programming models, performance tools, Big Data, computer architecture, energy efficiency



To develop and implement global and regional state-of-the-art models for short-term air quality forecast and long-term climate applications

To understand living organisms by means of theoretical and computational methods (molecular modeling, genomics, proteomics)

To develop scientific and engineering software to efficiently exploit super-computing capabilities (biomedical, geophysics, atmospheric, energy, social and economic simulations)

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What

Environmental forecasting

Why

Our strength …
… research …
… operations …
… services …
… high resolution …

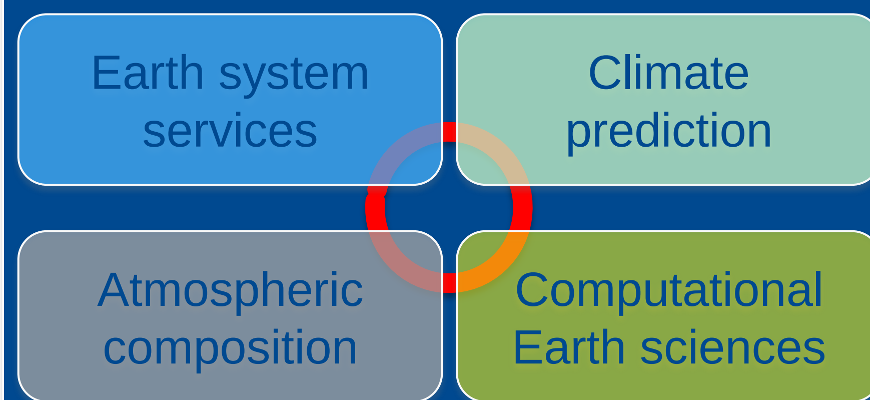
How

Develop a capability to model air quality processes from urban to global and the impacts on weather, health and ecosystems

Implement a climate prediction system for subseasonal-to-decadal climate prediction

Develop user-oriented services that favour both technology transfer and adaptation

Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models



C3S

From the Copernicus regulation (EU) 377/2014:

> "the Climate Change service (C3S) shall provide information to increase the knowledge base to support adaptation and mitigation policies. It shall in particular contribute to the provision of Essential Climate Variables (ECVs), climate analyses, projections and indicators at temporal and spatial scales relevant to adaptation and mitigation strategies for various Union's sectoral and societal benefit areas."

Climate Data Store

Sectoral Information System

Evaluation and Quality Control

Outreach and Dissemination

EQC challenges

- **EQC**: Evaluation and quality control
- **Address adaptation**: it must provide information for all kind of services including adaptation, taking advantage that many users are already familiar with the climate-change problem.
- **Provide consistency**: it must build trust, ensuring a high degree of coherence across products, underlying data sets, processing methods, communication, context, etc.
- **Provide innovation**: it should transfer recent developments from research to operations to answer real-world issues.
- **Address efficiency**: the EQC information should be timely, e.g. respond to users' queries with a delay as short as possible, which imposes conditions on the algorithms considered.
- **Define the target**: data, products, communication, etc.

What is EQC information

Some examples:

- Observations are expected to provide accuracy estimates.
- Reanalyses should come along with a validation against independent observations.
- Forecasts have no real value without an estimate of quality based on past performance.
- Projections require a scientific validation of the models used (e.g. IPCC WGI Ch. 9).

But quality information is much more complex than this.

QA4Seas: EQC for climate prediction

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QA4Seas aims at **developing a strategy for the evaluation and quality control (EQC) of the multi-model seasonal forecasts provided by the Copernicus Climate Change Service (C3S) to respond to the needs identified among a wide range of stakeholders**.

To achieve the objective the consortium:

- Considers the evaluation of multi-faceted quality aspects
- Is user driven with a two-stage consultation process (coordinated with other lots)
- Formulates requirements to the CDS to address user requirements
- Performs a gap analysis of the current information available to users
- Develops a framework and a prototype of the EQC system

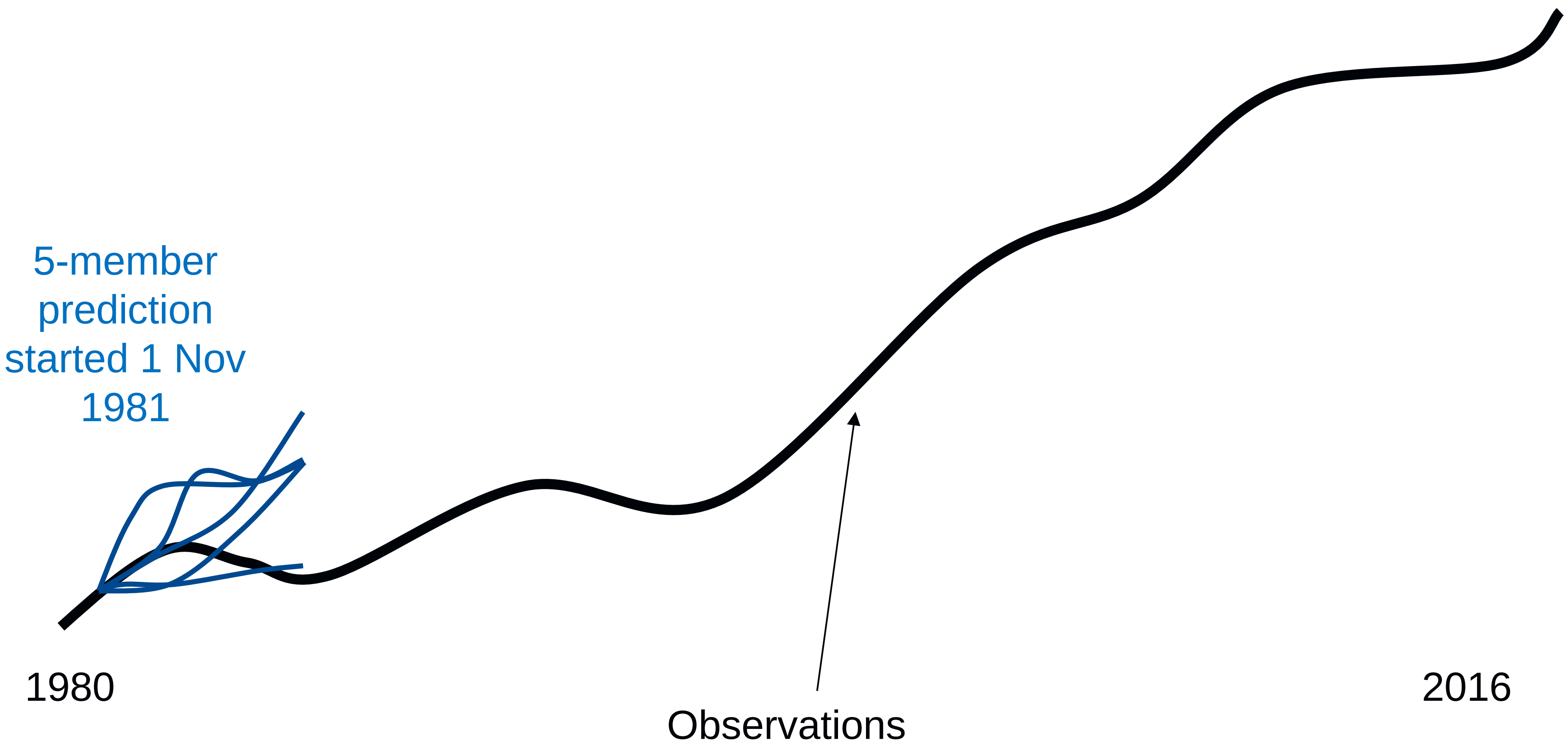
QA4Seas: Principles

- A prediction has no real value without an estimate of its quality based on past performance.
- QC is multifaceted, no single metric fully characterises the quality of a system or allows to single-out the best forecast system.
- It addresses administrative (tracks the system evolution), scientific (skill and reliability), or socio-economic (users' requirements) questions.
- QC of the European multi-model is not readily available, contrary to the Asian and North American one.
- **Climate service providers should consider the consequences of their actions for those who may be affected by the products**.
- **Climate service products should be open to scrutiny and comparison**.

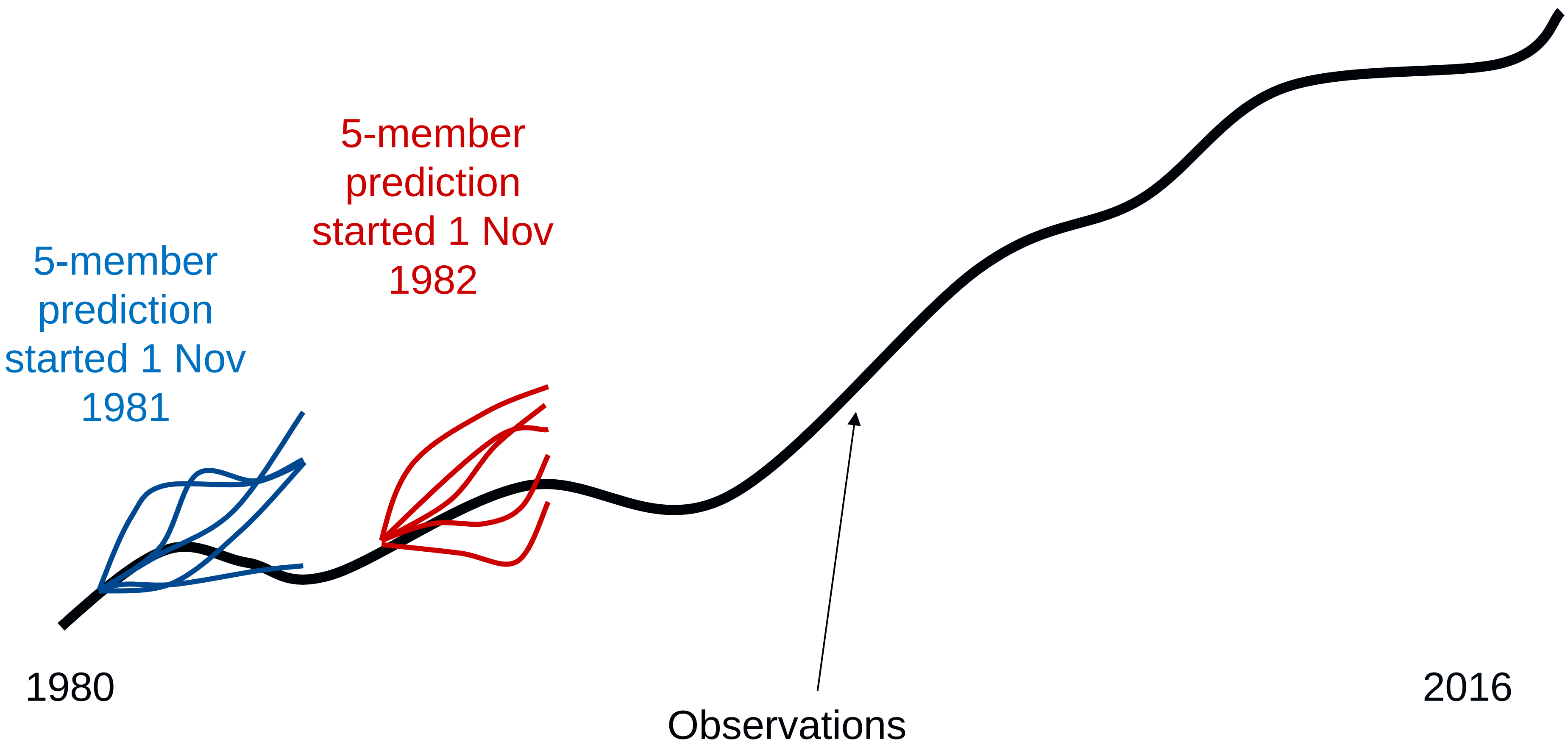
Climate prediction

- Models are initialised to address the internal variability uncertainty source and make a skilful forecast, one of the requirements is an accurate knowledge of the initial state of the system.
- Steps to initialise an ensemble climate forecast system:
  - make the most of the available observations to rebuild the best estimate of the system state (reanalysis)
  - transfer such information to the model avoiding imbalances, i.e. initialise the climate prediction system with the minimum shocks
  - run the ensemble with initial perturbations to account for the initial-state uncertainty

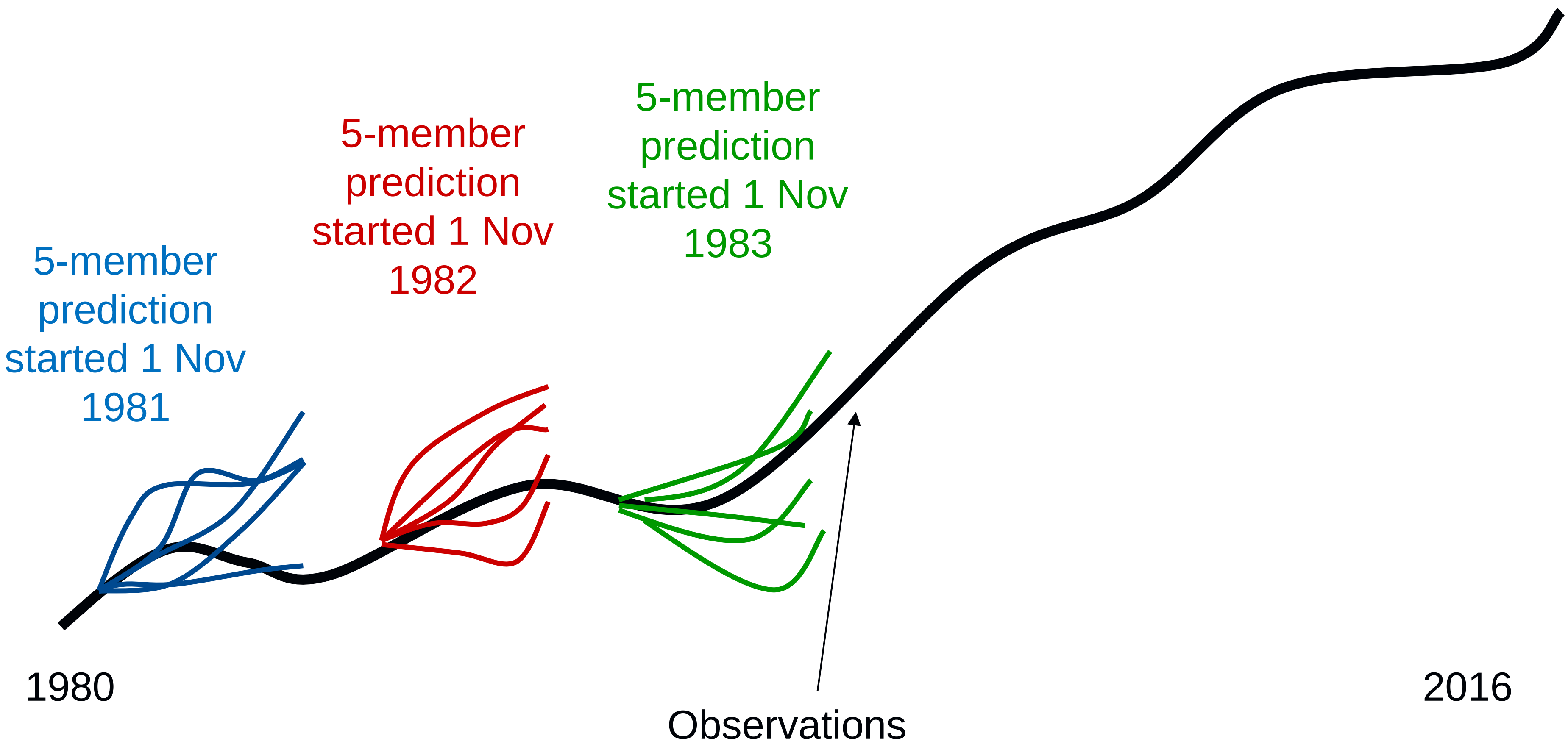
Climate prediction experiments



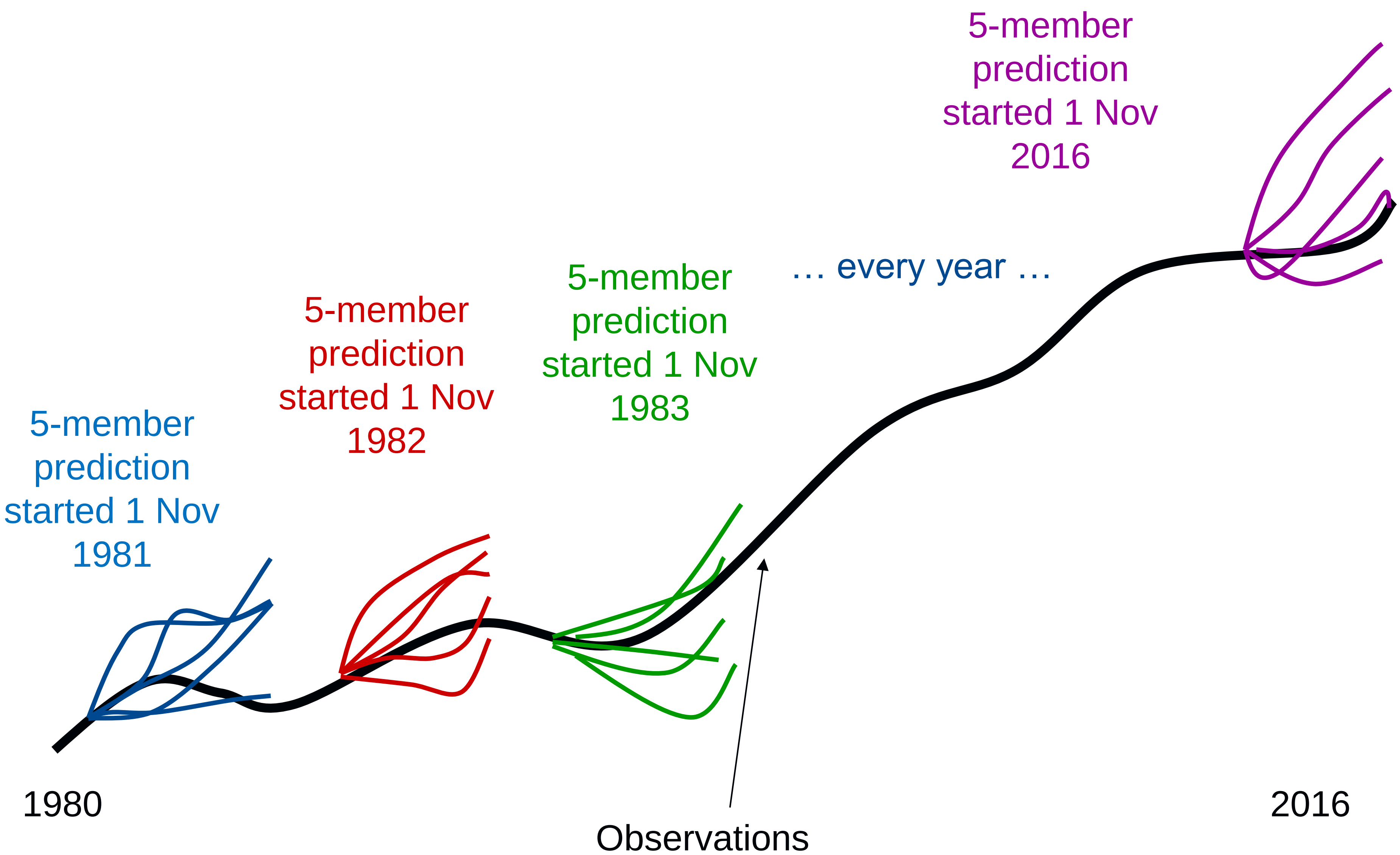
Climate prediction experiments



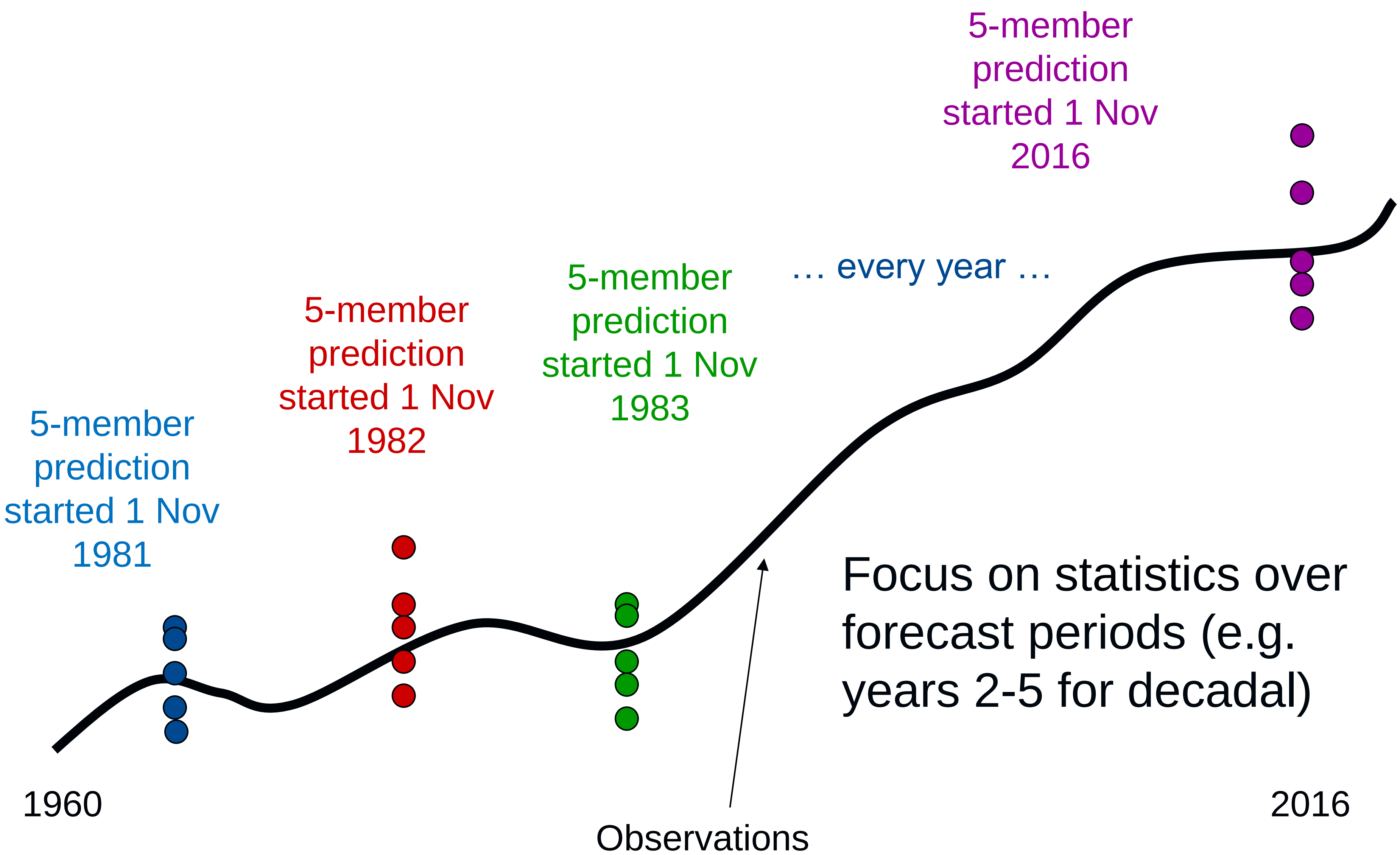
Climate prediction experiments



Climate prediction experiments

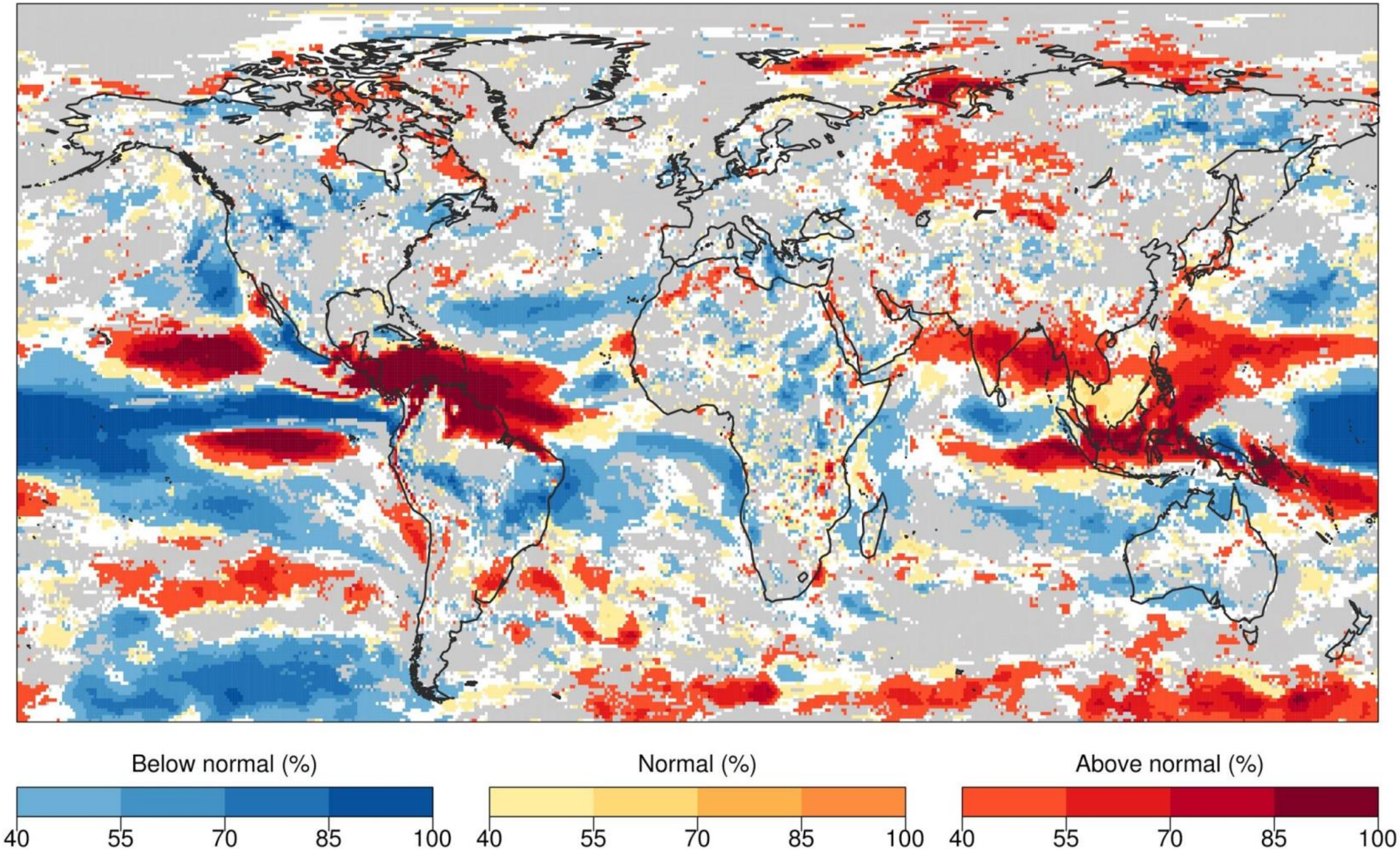


Climate prediction experiments



Focus on statistics over forecast periods (e.g. years 2-5 for decadal)

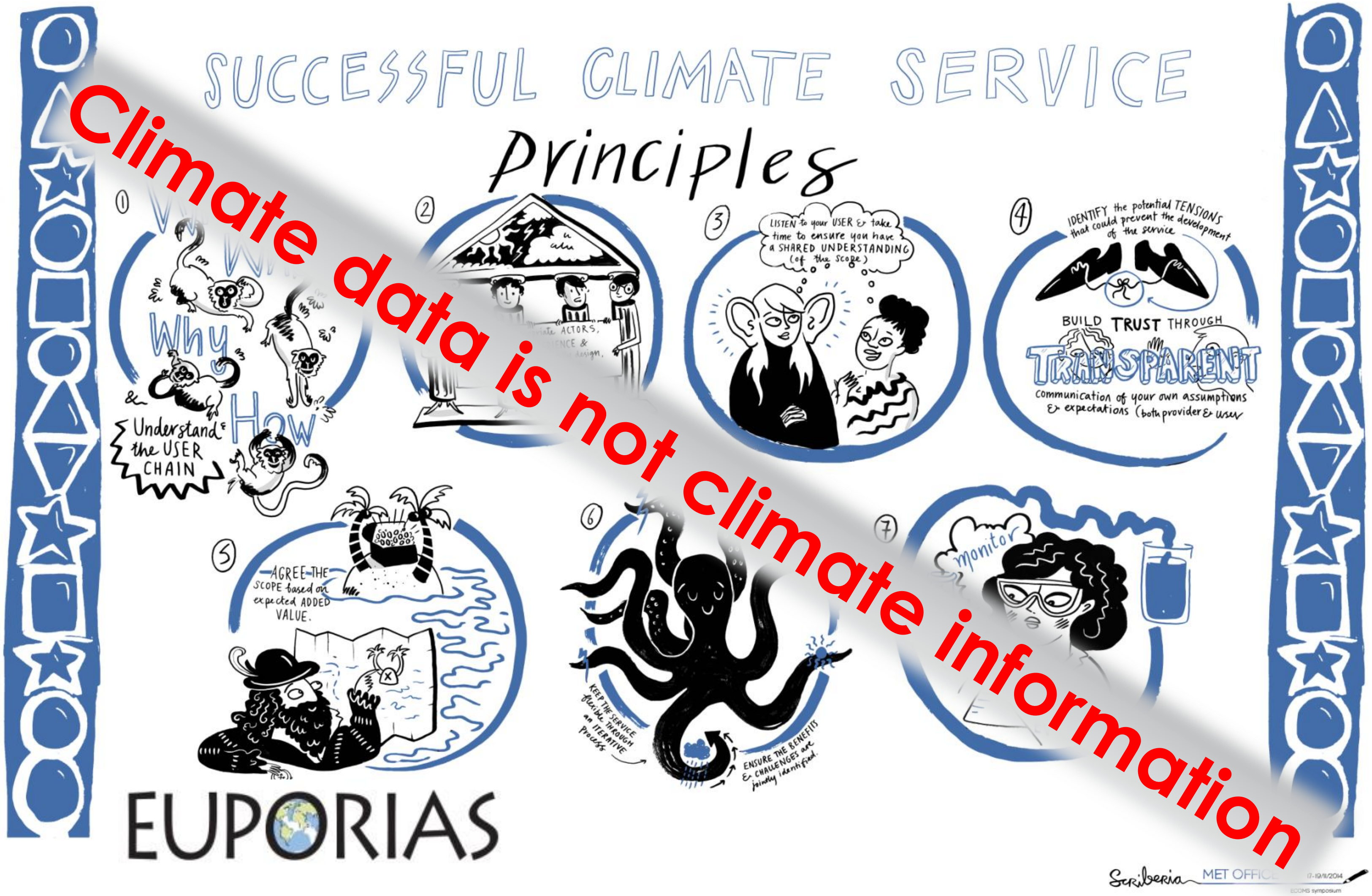
From ensembles to predictions



Wind speed prediction for June 1st - August 31st 2015, issued on May 1st 2005.

The most likely wind power category (below normal, normal or above normal), and its percentage probability to occur is shown. "Normal" represents the average of the past. White areas show where the probability is <40% and approximately equal for all three categories. Grey areas show where the climate prediction model does not improve upon the standard and current approach, which projects past climate data into the future.

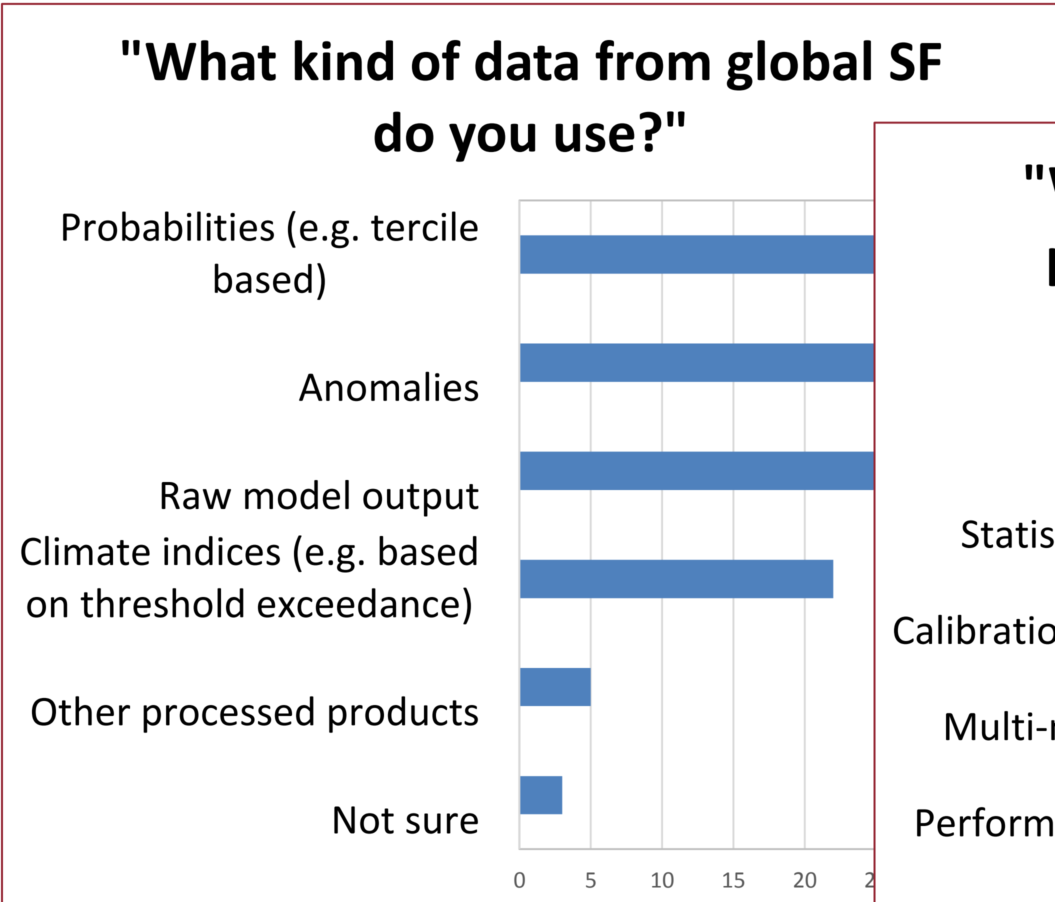
Service-driven climate research

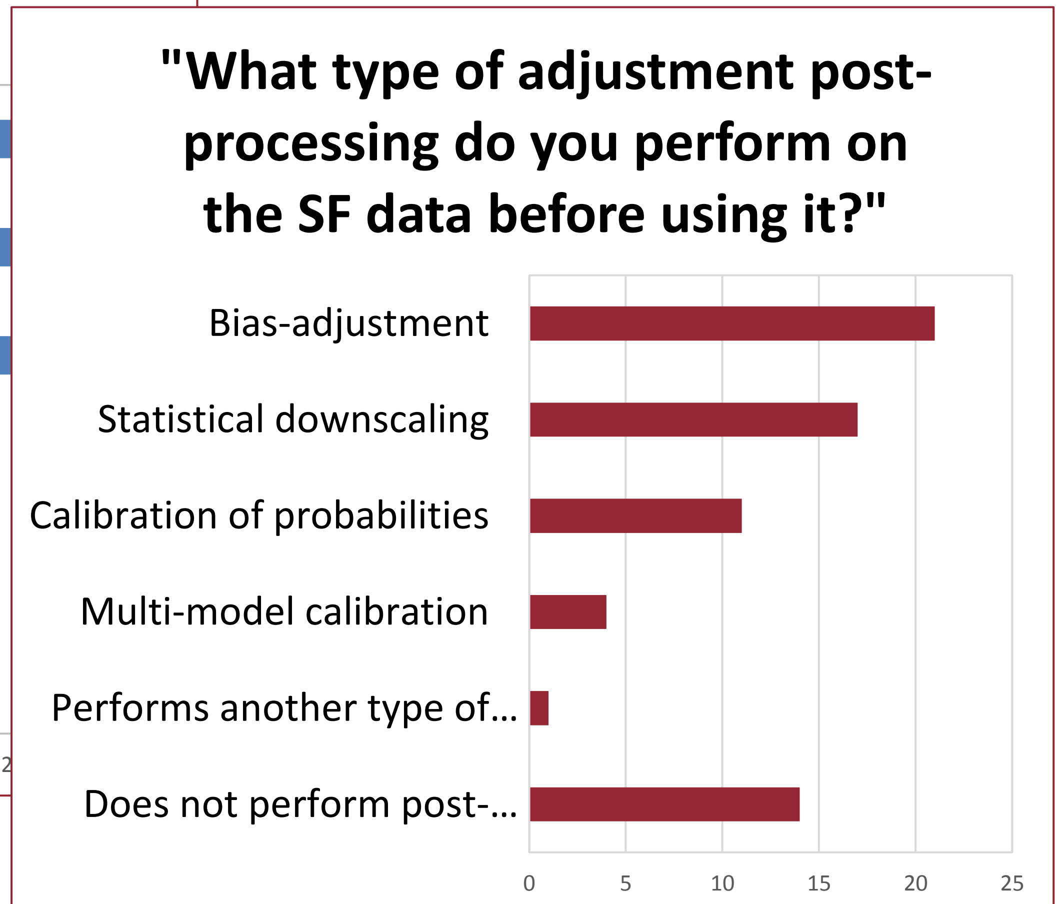


Climate data is not climate information

What do the users want?

Results from a user survey.





M. Soares (Univ. Leeds)

The building blocks

Existing R packages are used for both the preliminary assessment and the prototype. New elements (inference assessment, metadata propagation, etc.) are built in to address the C3S needs.

SCORES

SpecsVerification
- Probabilistic and deterministic scores
- Works on [time x members] arrays

easyVerification
- Applies SpecsVerification scores to arrays of any dimensions, multi-core
- Probabilistic and deterministic scores

FRAMEWORKS

downscaleR + loadeR
- Data retrieval and homogenization
- Bias adjustment, modes, downscaling
- Probabilistic and deterministic scores
- Visualisation of data and results

s2dverification
- Data retrieval and homogenization
- Bias adjustment, filtering, modes
- Probabilistic and deterministic scores
- Visualisation of data and results

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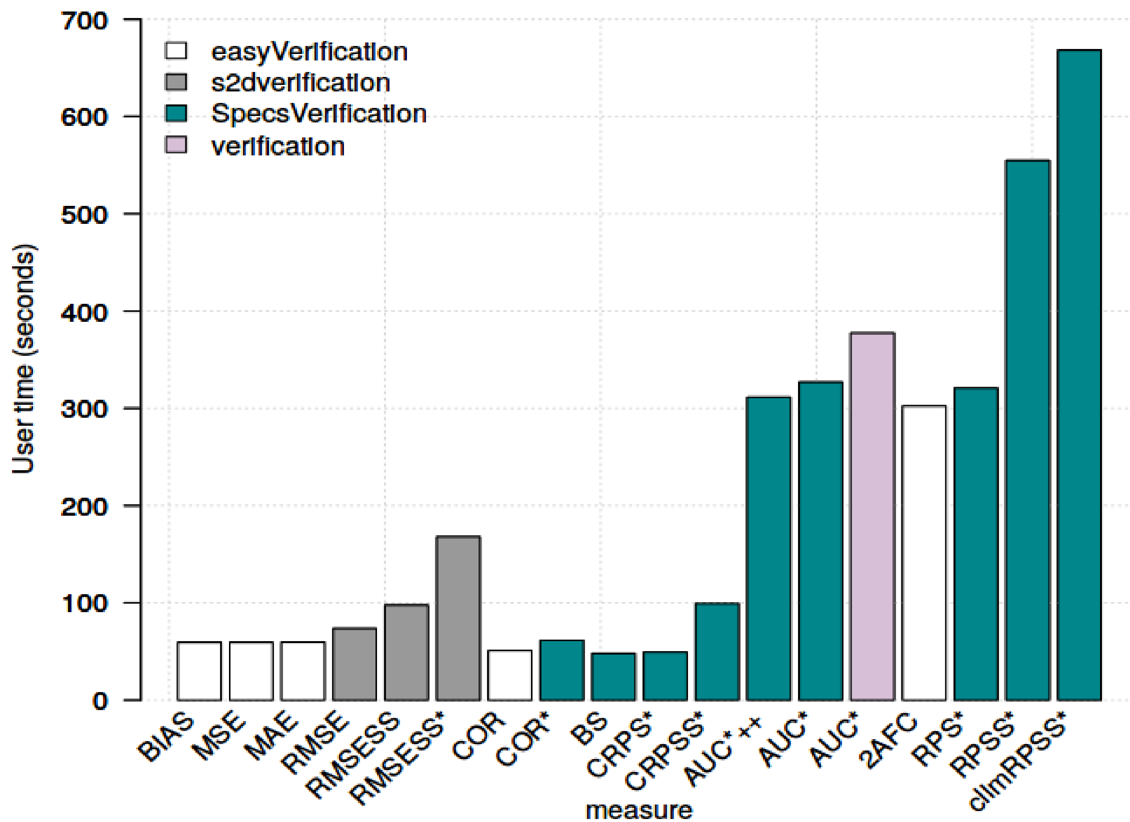
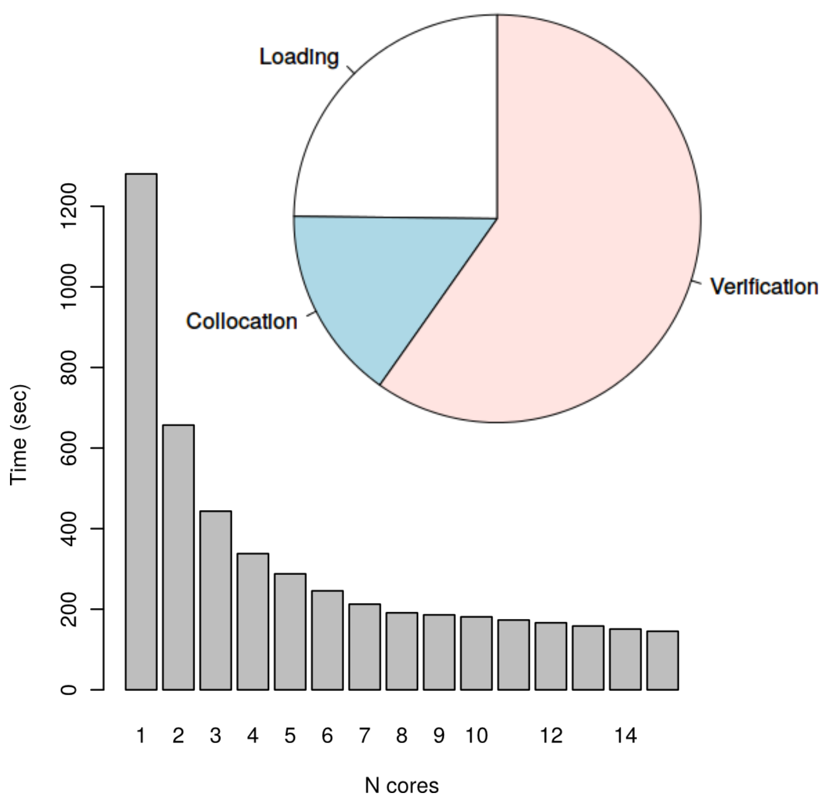
Computing performance is key: performance and efficiency (parallel scalability), which are evaluated in controlled environments, are part of the contract KPIs.

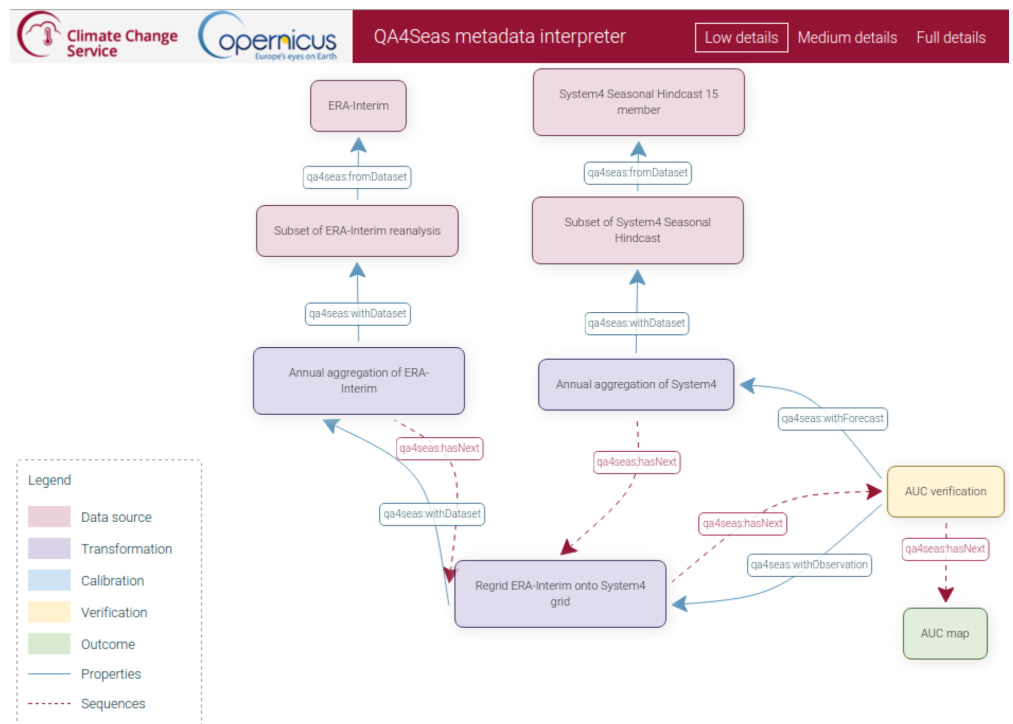


J. Bedia, D. San Martín (Predictia)

Improving diagnostics efficiency

- **Computing performance is key**: (left) scalability of a ROC area estimate using loadeR, SpecsVerification and easyVerification.
- An RDF-based approach aiming at the reproducibility of objects (NetCDF file, image) with human and machine-readable solution using a semantic metadata model has been created in QA4Seas.





The preliminary assessment

- A preliminary assessment of the current operational systems is carried out and made available through a shiny app.
- An updated version using a workflow manager is under preparation.

C3S_51 Lot3 WP3: preliminary scientific assessment

Display selection

Plot type:

Global maps

Models:

- [ ] C3S Multimodel
- [x] ECMWF System 4
- [x] Met Office GloSea5
- [x] MeteoFrance System5

Frequency:

Monthly

Variable:

Sea surface temperature

Initialization:

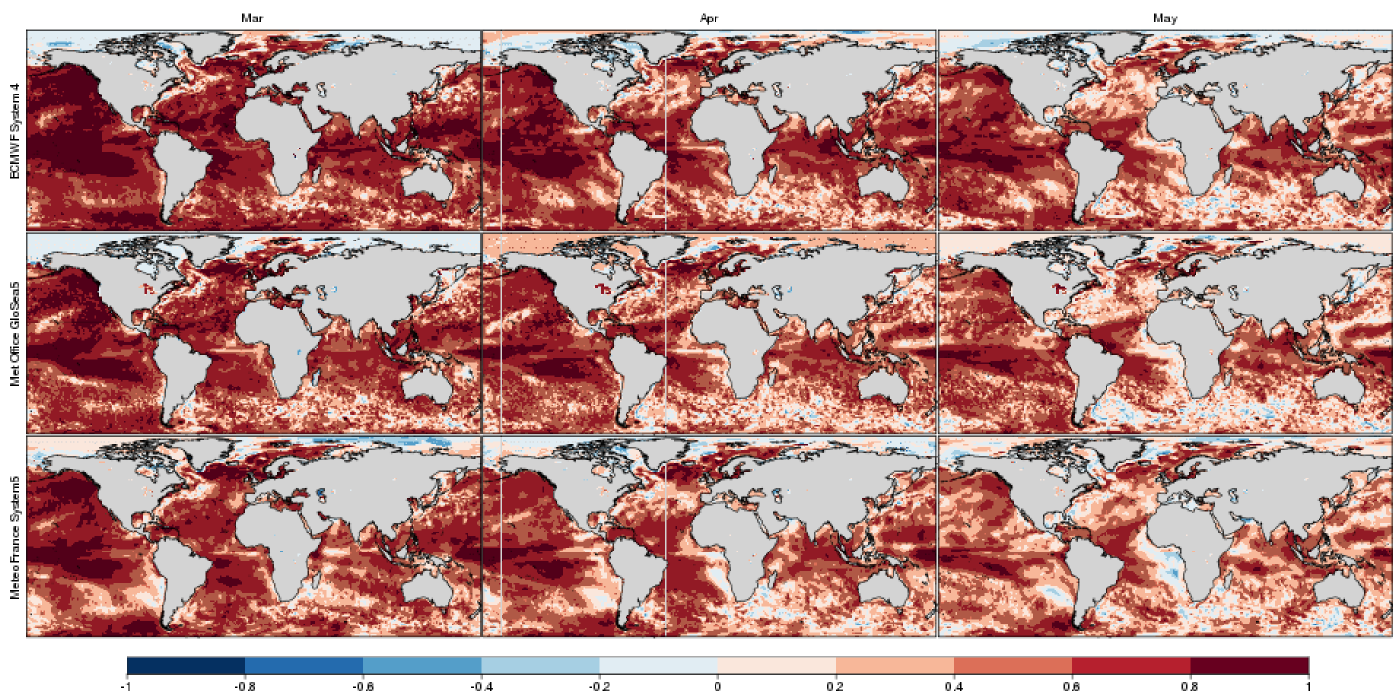
February

Product:

Anomalies

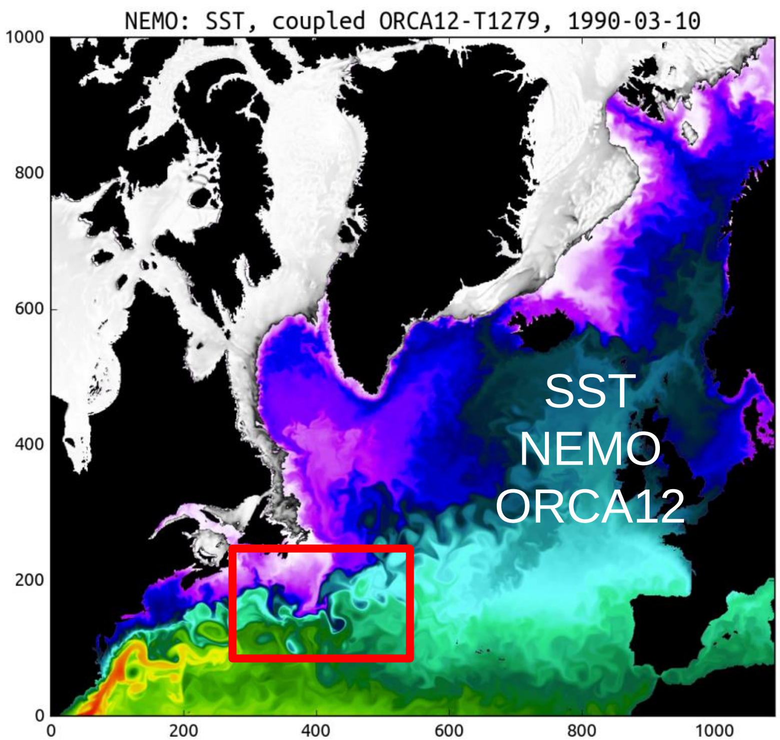
Score:

Correlation

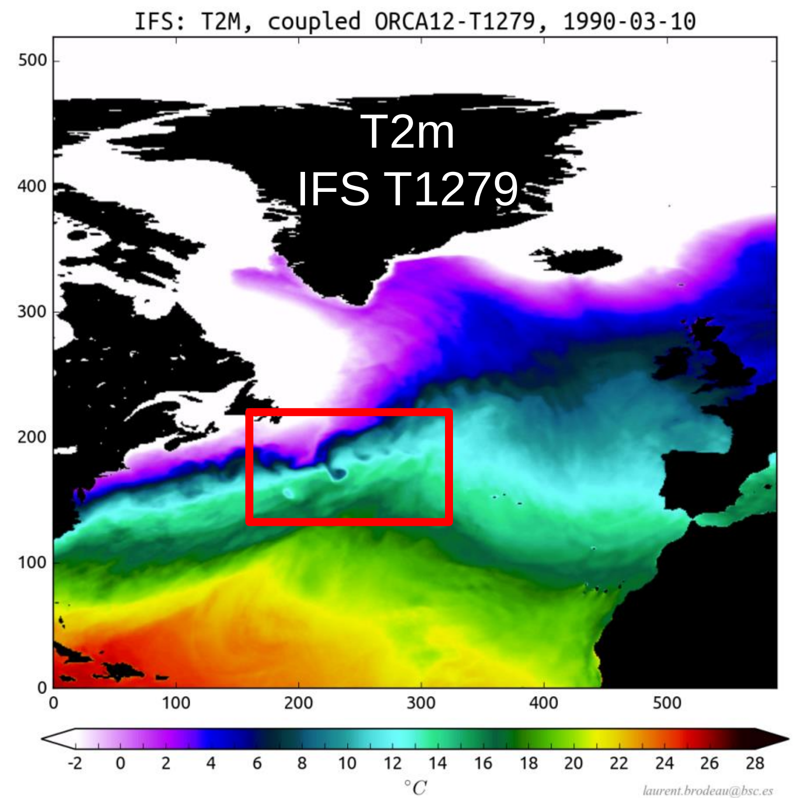


Generating plots with data from:

Global high resolution matters

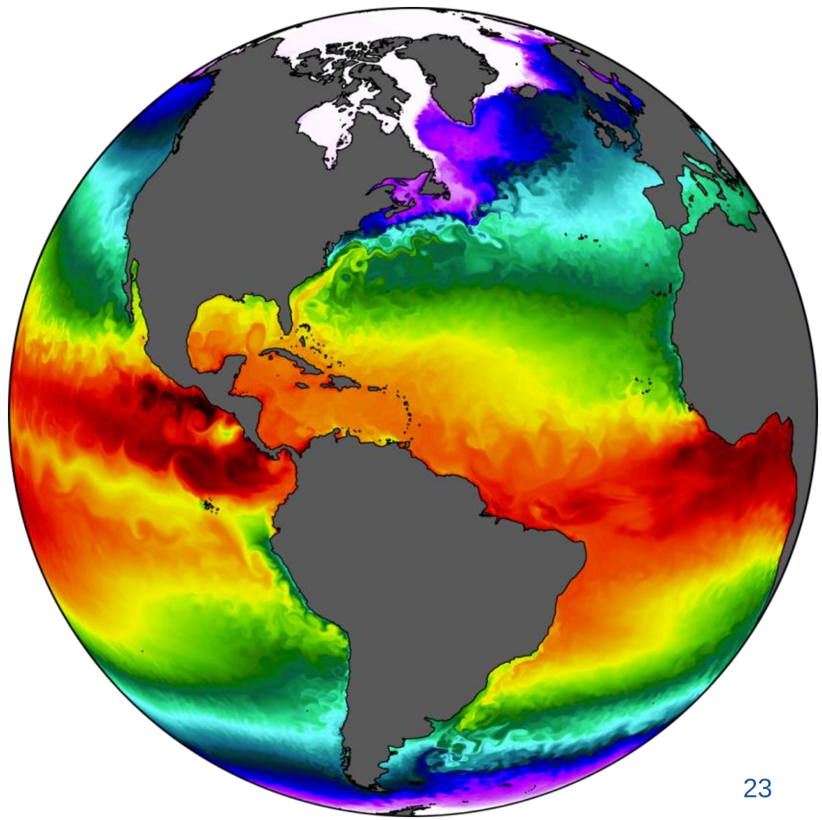


EC-Earth GLOBAL ORCA12-T1279
(ocean and atmosphere at ~10 km)

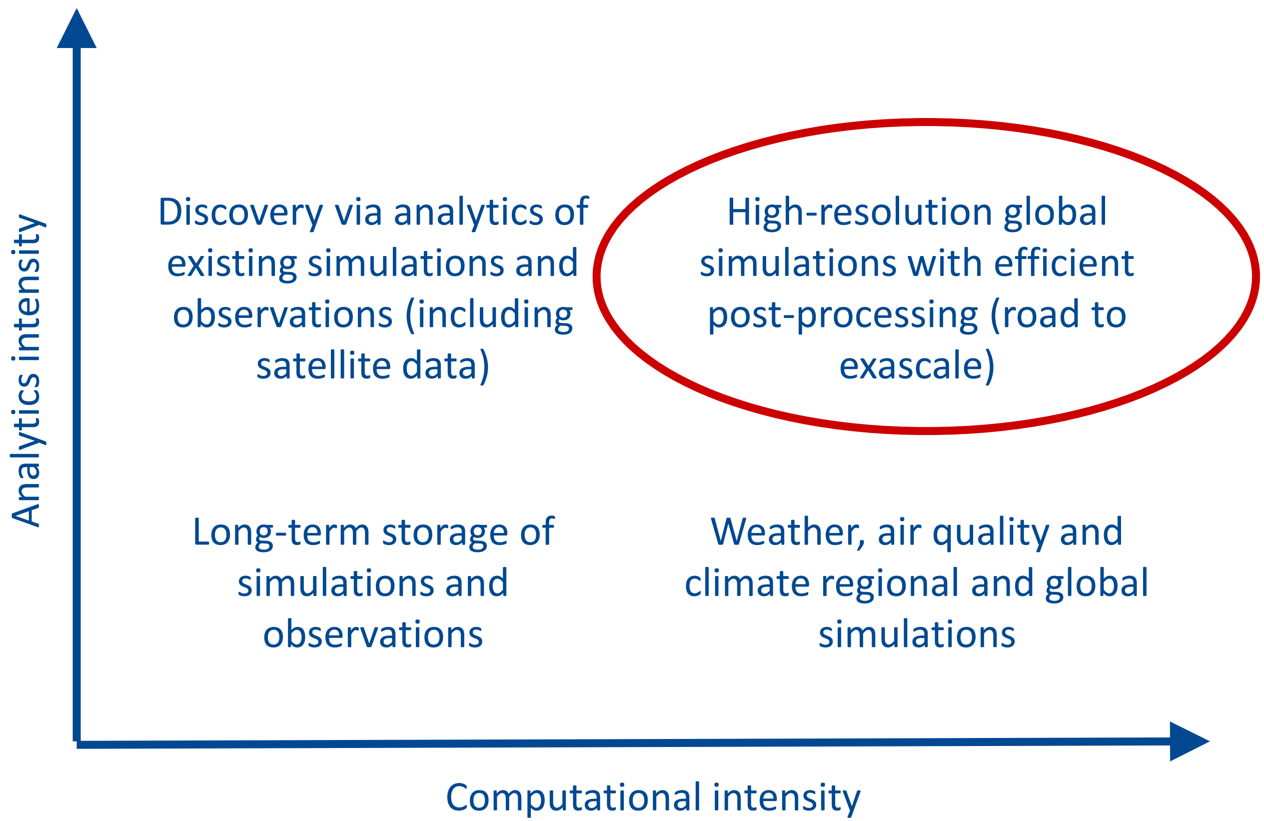


EC-Earth high resolution

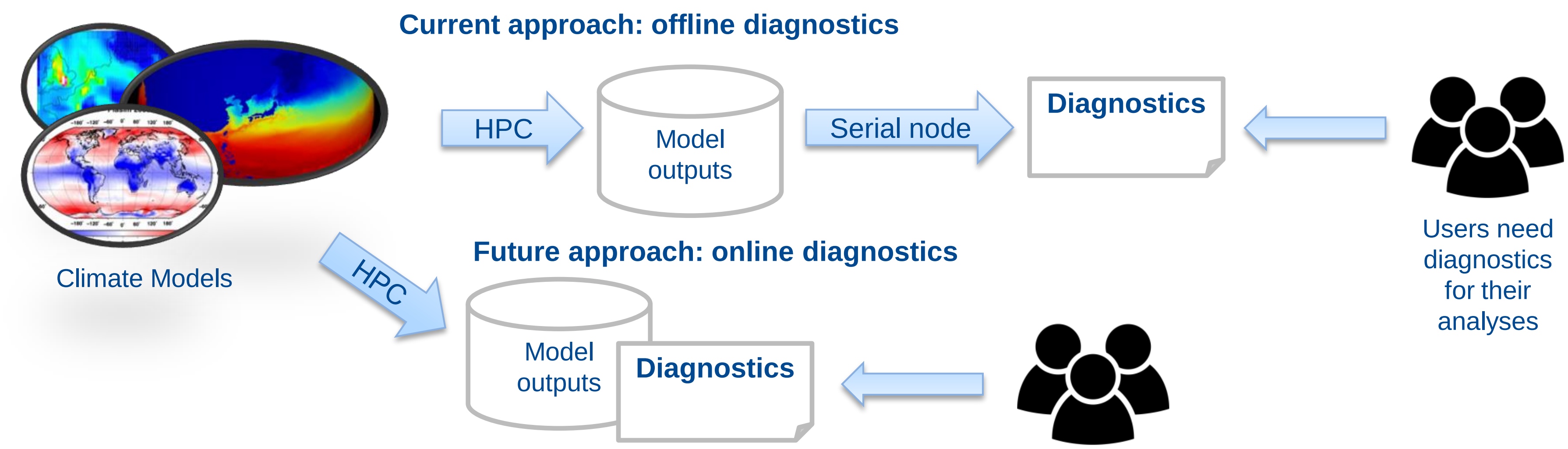
- The very high resolution configuration runs at ~10 kms
- The physical interaction between ocean and atmosphere is far more realistic at these resolutions
- 220 kCPUhours per simulated year (typical simulation is 150 years times several members)
- 5 TB I/O per simulated year
- Post-processing can reduce it to 350 GB per simulated year
- Data reduction requires analytics on the node (or on an accelerator)
- A handful of institutions are currently able to address the issue



HPC and data analysis



Improving diagnostics efficiency

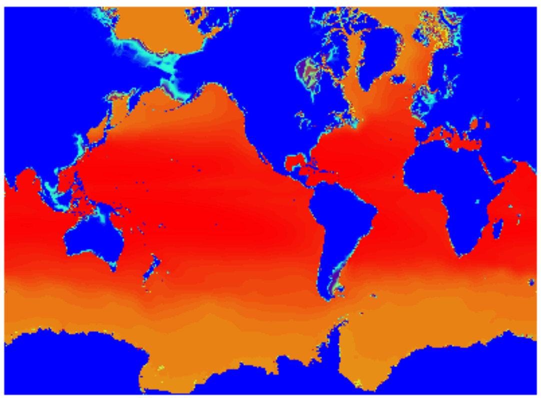


- Diagnostics computed as Analytics as a Service
  - Diagnostics online (during model run)
  - Reduced data traffic
  - Diagnostics possible on the computing nodes (using GPUs)
  - New diagnostics (data mining of extremes) possible
  - The user gets the results faster → crucial to adapt to climate change and to develop climate services (public and private)

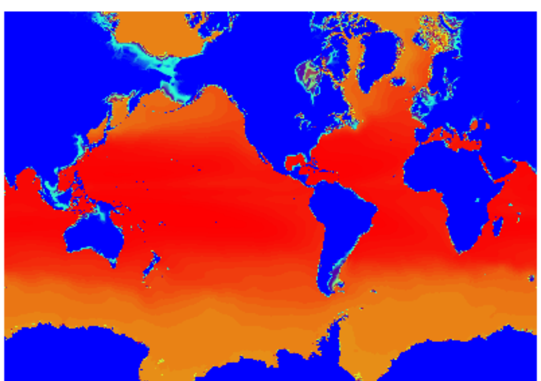
Diagnostics on GPUs

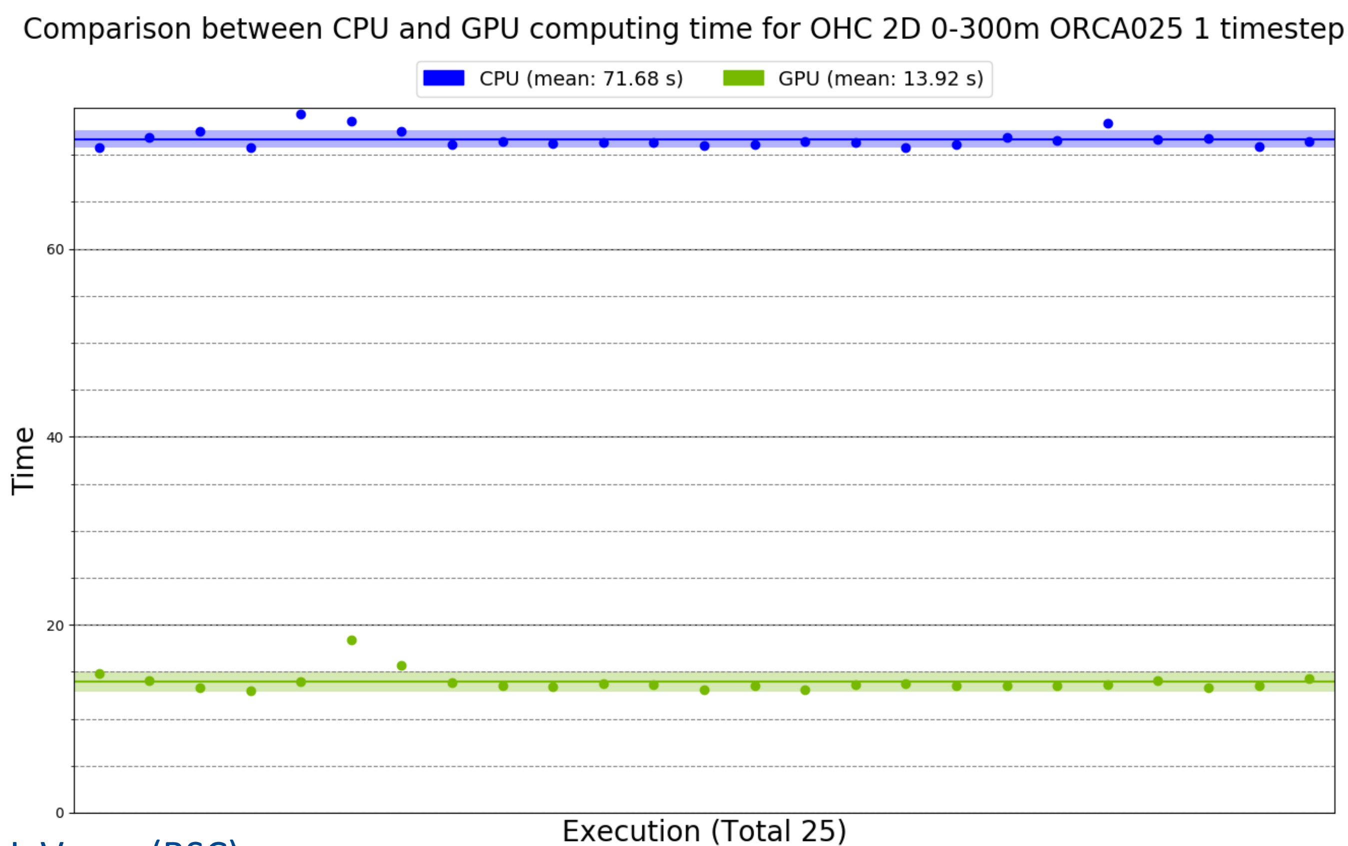
Ocean heat content from 0 to 300 metres depth for one month in the ORCA025 global grid (1442x1050x75). Irregular grid over x, y and z axis.

CPU



GPU

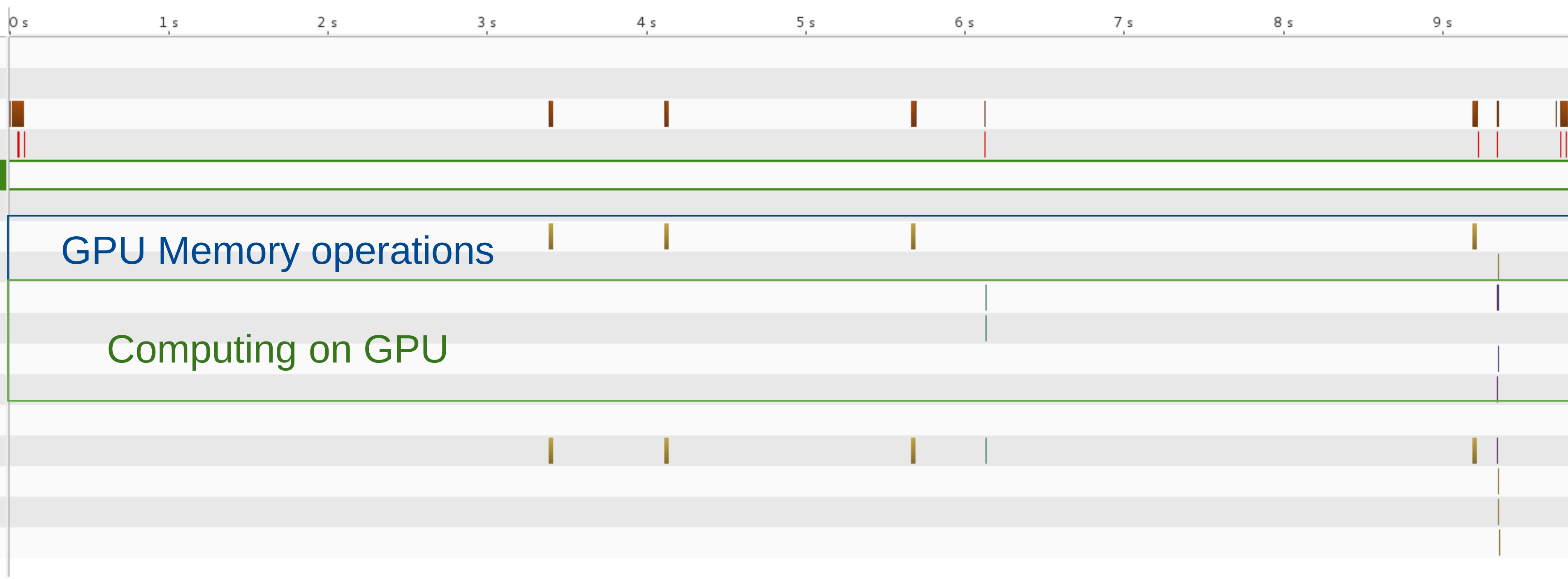




J. Vegas (BSC)

Diagnostics on GPUs

- Speed up of ~5x for one timestep
- Most of the time is spent just moving data from/to disk
  - Moving data to GPU memory: ~ 200 ms per execution
  - Computing time on GPU: ~ 5.5 ms !!!!
- Computing multiple diagnostics over the same data is almost free



J. Vegas (BSC)

Summary

- EQC is user driven, but user requirements are a moving target that also depends on the amount of information they receive.
- EQC information is not neutral, precise definitions are necessary, documentation (context, provenance) is key.
- Data inventories should identify gaps: relevance, metadata, etc.
- Existing packages are an invaluable source of solutions, and are considered within a framework that addresses adequacy, efficiency (parallelisation, workflow management, etc.) and provenance.
- The recognition of the future platform heterogeneity is the only way forward to optimise both time and resources.